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Variability of abdominal adipose tissue measurements using computed tomography in prepubertal girls

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OBJECTIVE: To determine the variability of measuring regional adipose tissue area using abdominal computed tomography (CT) in normal-weight, prepubertal girls.
DESIGN: Measurements of abdominal CT were performed twice, 6 weeks apart.
SUBJECTS: Sixty-one normal-weight, prepubertal girls (age: 4.8–10.3 y, mean (s.d.) BMI: 16.7 ± 1.5 kg/m^2).
MEASUREMENTS: Abdominal adipose tissue by CT at baseline and 6 weeks later.
RESULTS: There were no significant differences between visits 1 and 2 with regard to the children's average abdominal CT derived intraabdominal adipose tissue (21.64 cm^2 *vs* 23.74 cm^2) and subcutaneous adipose tissue (62.49 cm^2 *vs* 65.28 cm^2). The Pearson coefficient of correlation (*r*), *P*-value, total coefficient of variation (CV) and standard error of the difference (SE_Δ) for intra-individual measurements between visits 1 and 2 by abdominal CT were: total abdominal adipose tissue, $r = 0.94$, $P < 0.0001$, CV = 12.34%, SE_Δ 2.25 cm^2; subcutaneous abdominal adipose tissue, $r = 0.96$, $P < 0.0001$, CV = 10.67%, $SE_\Delta = 1.57$ cm^2; and intraabdominal adipose tissue, $r = 0.67$, $P < 0.0001$, CV = 21.5%, $SE_\Delta = 1.11$ cm^2. The mean ratios of intraabdominal to subcutaneous adipose tissue on visits 1 and 2 were 0.42 ± 0.2 and 0.44 ± 0.24, respectively.
CONCLUSION: Regional adipose tissue area measurements using abdominal CT were reliable in healthy, normal-weight, prepubertal girls.

Keywords: children; intraabdominal adipose tissue; subcutaneous adipose tissue

Introduction

In adults, increased intraabdominal adipose tissue, or visceral fat is an important metabolic risk factor for the metabolic complications of excess adiposity.[1,2] Intraabdominal adipose tissue has been related to dyslipidemia and glucose intolerance in obese children and adolescents.[3–5] Intraabdominal adipose tissue has also been observed in healthy, non-obese children as young as 4–7 years[6] and in non-obese adolescents.[7,8] The availability of *in vivo* imaging techniques (for example, magnetic resonance imaging and computed topography (CT)) has led to significant advances in our understanding of the physiology of intraabdominal adipose tissue[2,9,10] and its relation to negative health effects.[11] One study, using CT scans in prepubertal children demonstrated that the accumulation of intraabdominal adipose tissue was highly variable.[12] In a study in adults, 16 women (lean to obese) underwent duplicate abdominal CT scans, standing after the first and then repositioning prior to a repeat CT scan.[13] The reproducibility of CT in this study in adults was demonstrated by a high correlation between duplicate measurements (***r*** $= 0.99$, $P < 0.01$), and by small precision errors (calculated as the standard error of single determination and expressed as the percentage of the mean); 1.2% of the mean value of total adipose tissue cross sectional area, 1.9% for subcutaneous adipose tissue area, and 3.9% for visceral adipose tissue area.[13] However, body composition is inherently different in children because of growth and development. In addition, children are found to be in the lowest part of the intraabdominal adipose tissue spectrum,[6–8,12] and for future studies it is crucial to know the reliability of CT measures at he lower end of the spectrum. In children the abdominal adipose tissue measurements may be less reliable because there is a lower amount of adipose tissue and there is greater potential for movement during the test. Therefore, this study was undertaken to examine the variability of abdominal CT measurements in normal-weight, prepubertal girls. This objective was met by obtaining abdominal CT measurements in prepubertal girls twice, 6 weeks apart.

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Methods

Subjects

Sixty-one healthy girls aged 4.8–10.3 y were studied. All girls weighed < 120% of ideal body weight-for-height using standards from the National Center for Health Statistics.[14] All girls were prepubertal, Tanner Stage I.[15] They were not consuming special diets, participating in extreme exercise programs, or taking any medications. The children were recruited from schools in the Birmingham area. Before enrollment, each child was familiarized with the procedures and equipment used for the body composition measurements through a demonstrative interview. The purpose of the study was explained to the children and their parents before informed written consent/assent was obtained. The Institutional Review Board of the University of Alabama at Birmingham approved this study.

Regional adipose tissue area

On two occasions, 6 weeks apart, regional adipose tissue area was measured directly by abdominal CT (HiSpeed Advantage Scanner, General Electric Corp., Milwaukee, WI) at the University Hospital of Alabama at Birmingham. A single slice (5-mm thickness) at a low X-ray dose rate (0.2 rad) was performed, at the level of the umbilicus, which corresponds to the level of the 4th lumbar vertebra. The narrow slice thickness and low dose rate greatly reduce the amount of absorbed ionizing radiation to acceptable levels for studying children (the absorbed radiation is less than a standard chest X-ray). The child was examined in the supine position with her arms stretched above her head. CT-scan data are expressed as cross-sectional area of adipose tissue (cm^2). Total abdominal adipose tissue area was later calculated using commercially available CT software (General Electric Medical Systems, Milwaukee, WI). Adipose tissue area was determined electronically by setting the region of interest for attenuation values within the range of −30 to −190 Hounsfield units.[16] The boundary separating subcutaneous and intraabdominal adipose tissue was defined manually using a cursor. The areas of intraabdominal adipose tissue and the entire adipose tissue area of the abdominal scan were electronically calculated, and subcutaneous adipose tissue was calculated as the difference.[17] All scans were performed by certified radiology technicians. One investigator completed all analyses.

Statistical analysis

The data were reported as percentages, means ± s.d.s, intra-individual coefficients of variation (CVs), and standard errors of the difference (SE_Δ) between the two units. Paired *t*-tests were utilized to assess the change in adipose tissue between the two visits, 6 weeks apart. The average intra-individual CV is found by averaging the CV for each of the 61 girls. Pearson's coefficient of correlation (***r***) was used to compare the abdominal CT scan measurements at the two visits for each child. Standard error of the difference (SE_Δ) between the two visits is another measure that assesses the variability of these measurements across time, along with the intra-individual CVs and Pearson's correlation coefficients. All statistical analyses were completed by using the Statistical Analysis System, SAS Windows Version 4.0.950, on a Gateway P5-120 personal computer.[18]

Results

Demographic and physical characteristics of the 61 girls are shown in Table 1. There were no significant differences between visits 1 and 2 for intraabdominal and subcutaneous adipose tissue by abdominal CT, Table 2. The ***r***, *P*-value, CV and SE_Δ in intra-individual measurements between visits 1 and 2 by abdominal CT were as follows: total abdominal adipose tissue, $r = 0.94$, $P < 0.0001$, CV = 12.34%, $SE_\Delta = 2.25\ cm^2$; subcutaneous abdominal adipose tissue,

Table 1 Demographic and physical characteristics of the 61 prepubertal girls at enrollment

Characteristics	*Mean ± s.d.*
Age (y)	7.3 ± 1.3 (4.8–10.3)
Race:	
White (*n*)	52
African-American (*n*)	8
Asian-American (*n*)	1
Weight (kg)	27.17 ± 5.2 (16.2–42.0)
Height (cm)	126.8 ± 8.8 (103.0–149.0)
Body mass index (kg/m²)	16.7 ± 1.5 (14.0–20.0)

Data shown as mean ± s.d. (range).

Table 2 Variability of abdominal adipose tissue areas by computed tomography (CT) measurements in 61 prepubertal girls during two visits six weeks apart (mean ± s.d.)

Tissue area	*Visit 1 (cm²)*	*Visit 2 (cm²)*	*SEΔ (cm²)**	*CV (%)***
Intraabdominal adipose tissue	21.64 ± 8.7	23.74 ± 10.6	1.11	21.5
Subcutaneous abdominal adipose tissue	62.49 ± 36.7	65.28 ± 37.5	1.57	10.7
Total abdominal adipose tissue	84.13 ± 43.1	89.02 ± 45.1	2.25	12.3

There were no significant differences between visits.
* Standard error of the difference (SE_Δ) = s.d.$_\Delta\sqrt{}$n.
** Intra-individual coefficient of variation (CV) = (s.d./mean) × 100.

$r = 0.96$, $P < 0.001$, CV = 10.67%, $SE_\Delta = 1.57\,cm^2$; and intraabdominal adipose tissue, $r = 0.67$, $P < 0.0001$, CV = 21.5%, $SE_\Delta = 1.11\,cm^2$ (Figures 1 and 2 and Table 2). The mean ratios of intraabdominal to subcutaneous adipose tissue on visits 1 and 2 were 0.42 ± 0.2 and 0.44 ± 0.24, respectively. The inter-individual CVs for total abdominal adipose tissue was 50.9%, subcutaneous abdominal adipose tissue was 58.1%, and intraabdominal adipose tissue was 42.4%; demonstrating a high degree of inter-individual variability in our cohort of girls.

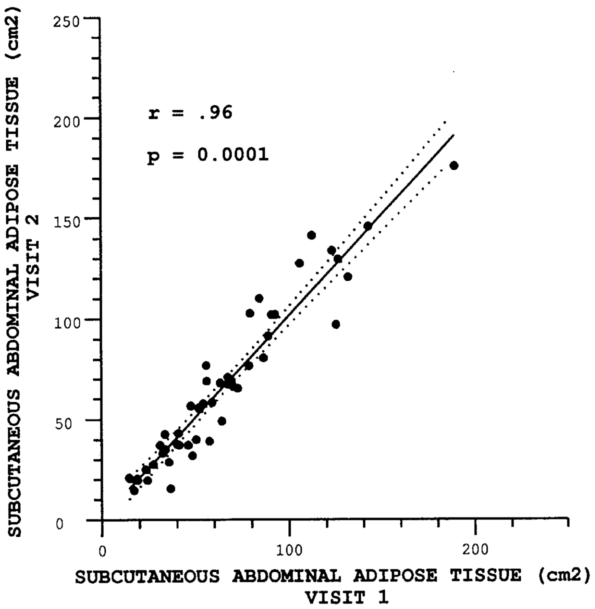

Figure 1 Comparison of subcutaneous abdominal adipose tissue (cm^2) on two visits six weeks apart by computed tomography (CT). The two dotted lines indicate the 95% confidence interval.

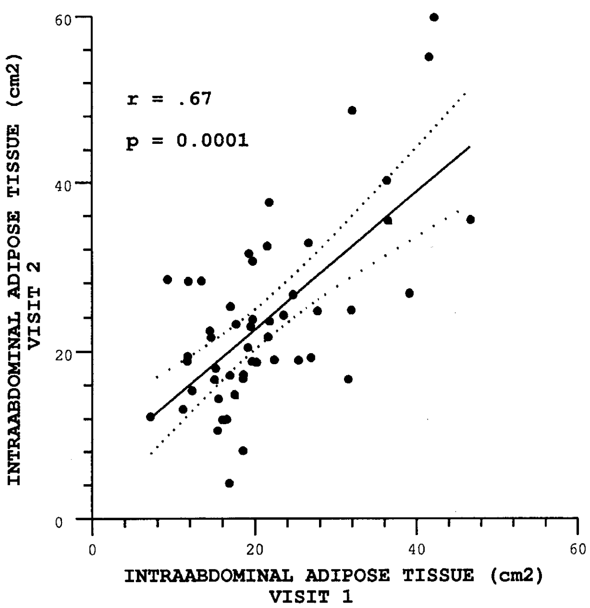

Figure 2 Comparison of intraabdominal adipose tissue (cm^2) on two visits six weeks apart by computed tomography (CT). The two dotted lines indicate the 95% confidence interval.

Discussion

This is the first study in children to demonstrate the variability of regional adipose tissue area measurements using CT in healthy, normal-weight, prepubertal girls. The slight inflation of the CV for intraabdominal adipose tissue area relative to subcutaneous and total abdominal adipose tissue area is not due to the variability in our measurements, but from the relative small average amount of intraabdominal adipose tissue area in these children. Intra-individual CVs are calculated by taking each individual's CV, then averaging across the cohort. This is consistent with paired comparisons when we have paired CVs on individuals. As can be seen in Table 2, the SE_Δ for intraabdominal adipose tissue ($1.11\,cm^2$) is actually slightly less than that for both subcutaneous ($1.57\,cm^2$) and total abdominal adipose tissue ($2.25\,cm^2$), whereas the average adipose tissue area at each visit for intraabdominal adipose tissue is much less. This results in a much smaller denominator in the calculation of the CV for intraabdominal adipose tissue area and inflates its corresponding CV. Furthermore, biological variability (growth) is also responsible for some of the CV and SE_Δ variation in the two abdominal CT measurements.

The children's growth during the 6 weeks interval is a limitation of this study. This study was conducted as a subproject of a larger investigation funded by the National Institutes of Health of metabolic predictors of weight gain in normal-weight, prepubertal girls. Because of the timing and magnitude of other tests involved in the protocol, that is, biochemical parameters, metabolic, and exercise tests during a 4-d stay at the General Clinical Research Center, we could not ask children and their parents to submit for repeat testing in a shorter interval of time. The 6-weeks interval of time of retesting of the abdominal CT measurements introduces the confounding influence of growth. However, the on-going longitudinal study of further abdominal CT testing will explain the influence of different stages of growth and development on this cohort of children.

The clinical implication of our intraabdominal adipose tissue finding can be explained as follows. A change of one-half of a standard deviation in intraabdominal adipose tissue accumulation would indicate a clinically significant change. In our data, that is equivalent to a change of $4.3\,cm^2$ or approximately 0.8 inches. A sample size of 61 girls gives us 97% power to detect a clinically significant change of $4.3\,cm^2$ in intraabdominal adipose tissue, which is 0.5 s.d.s, with a Type I error of 5%. We found an actual change of intraabdominal adipose tissue of $2.1\,cm^2$ (23.74 minus $21.64\,cm^2$, Table 2). This is a change of 0.24 s.d., which is not clinically or statistically significant.

Our study presents data supporting the existence of intraabdominal adipose tissue (mean on two visits

6 weeks apart, 21.64 cm^2 *vs* 23.74 cm^2) in 5 to 10-y-old girls using CT. Other studies[6–8,12] have detected intraabdominal adipose tissue in children and adolescents using CT[6,12] and magnetic resonance imaging[7,8] abdominal slices at the level of the umbilicus. In our study as well as other studies[6,12] using CT, the reduced scan time (1 s) and slice thickness (5 mm) greatly reduced the radiation dose to acceptable levels for studying children. Using magnetic resonance imaging, intraabdominal adipose tissue was 24.1 ± 4.1 cm^2 and 25.7 ± 4.1 cm^2, in 11 and 13-y-old girls, respectively.[8] In other studies, intraabdominal adipose tissue was 17.8 ± 10.0 cm^2 and 24.8 ± 8.8 cm^2 in 11-y-old boys and girls, respectively.[7,8] In both studies[7,8] there was wide variation in intraabdominal adipose tissue area (ranges, 6–58 cm^2 in 11-y-old boys, and 15–50 cm^2 in 11-y-old girls). Using CT, intraabdominal adipose tissue was 8.3 ± 5.8 cm^2 (range, 2–24 cm^2) in 16 boys and girls ranging in age from 4–9 y old; and it was 31 ± 22 cm^2 (range, 7–102 cm^2) in 101 boys and girls ranging in age from 4 to 10 y old.[6,12] Thus, our values of intraabdominal adipose tissue (range, 4.22–59.95 cm^2) are similar to those previously reported in children and adolescents.

The metabolic complications associated with intraabdominal adipose tissue deposition in childhood[3–5] and adults[1,2] are well known. Thus, excessive accumulation of intraabdominal adipose tissue, but not subcutaneous adipose tissue, is known to be associated with cardiovascular risk factors in the pediatric population.[4,5] In adults, research is now focusing on the causes of intraabdominal adipose tissue patterning and methods to prevent intraabdominal adipose tissue deposition.[19] Nuclear magnetic resonance imaging and CT have been used to determine the extent and type of abdominal adipose tissue distribution. Besides the amount of intraabdominal adipose tissue, the ratio between intraabdominal and subcutaneous abdominal adipose tissue has been used to define the pattern of abdominal adipose tissue deposition.[7] Scores > 0.4 in obese adults have been categorized as predominantly visceral-type deposition and have been associated with greater metabolic complications.[8] In contrast to adults, obese boys and girls tend to have low intraabdominal to subcutaneous adipose tissue ratios, suggesting that excess adipose tissue storage is initially subcutaneous rather than visceral.[7] Our results differ from those of obese children.[7] In our cohort of healthy, normal-weight, prepubertal girls the intraabdominal to subcutaneous abdominal adipose tissue ratios for the visits were 0.42 and 0.44, respectively. Our findings concur with a recent study[12] in prepubertal children in which there were significant relationships between intraabdominal adipose tissue and subcutaneous adipose tissue ($\boldsymbol{r} = 0.87$, $P < 0.001$) as well as between intraabdominal adipose tissue and total body fat ($\boldsymbol{r} = 0.83$, $P < 0.001$). Because intraabdominal adipose tissue, subcutaneous adipose tissue, and total body fat were strongly interrelated, the investigators[12] suggested developing an index of intraabdominal adipose tissue that was independent of other obesity indexes. When intraabdominal adipose tissue was controlled for subcutaneous adipose tissue, there was no significant partial correlation of intraabdominal adipose tissue with total body fat.[12] Thus, the excess accumulation of abdominal fat in the intraabdominal relative to the subcutaneous region was independent of total body adiposity.[12] Therefore, they proposed that the residual from a regression between intraabdominal adipose tissue and subcutaneous adipose tissue could be viewed as an index of visceral fat that is independent of total body fatness.[12]

In conclusion, regional adipose tissue area measurements using abdominal CT were reliable in healthy, normal-weight, prepubertal girls. These results also confirm the existence of intraabdominal adipose tissue in prepubertal girls. Further research is required to track changes throughout puberty and to link metabolic and biochemical parameters with intraabdominal adipose tissue deposition in children and adolescents.

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